

## Vegetation classification in a floristically complex area: the Agulhas Plain

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The vegetation of the Agulhas Plain was classified and described using Campbell's (1985) approach. Data collected included a subset of Campbell's structural and higher taxon characters, as well as dominant (> 10% cover) species, which would enable the recognition of communities to at least the sub-series level in his hierarchy. The classification was produced using the Braun–Blanquet method of table sorting. Nine zonal communities, at various hierarchical levels, were recognized and mapped. Non-fynbos communities included Forest & Thicket, and Renoster Shrubland. Fynbos communities, which covered most of the study area, were Mesotrophic Asteraceous Fynbos, Dune Asteraceous Fynbos, Dry Restioid Fynbos, *Protea repens* Proteoid Fynbos, *Protea obtusifolia*–*Leucadendron meridianum*/P. *susannae*–*L. coniferum* Proteoid Fynbos, *L. platyspermum*–P. *compacta*–*L. xanthoconus* Proteoid Fynbos and Mesic Ericaceous Fynbos. It was not possible to classify Forest & Thicket below the group level while a new concept (Dune Asteraceous Fynbos) was developed at the sub-series level. In all other respects the largely lowland vegetation of the Agulhas Plain could be integrated with Campbell's Fynbos Biome mountain vegetation concepts. This study therefore demolished any justification for retaining a lowland fynbos vegetation concept. Since we utilized the skills of a number of trained botanists in collecting easily recognizable structural, and limited floristic data, the entire study was completed in under 18 months. The mapped communities are adequate for conservation planning and comprise an essential descriptive basis for future studies on the evolution and maintenance of species diversity on the Agulhas Plain. The efficiency and effectiveness of our approach makes it suitable as a model for rapid vegetation classification of the much-threatened vegetation of the fynbos biome lowlands.

Die plantegroei van die Agulhasvlakte word geklassifiseer en beskryf deur gebruik te maak van Campbell (1985) se benadering. Die gegewens wat versamel is, bevat 'n subgroep van Campbell se strukturele en hoër taksonkarakters, sowel as dominante (> 10% bedekking) spesies, wat die uitkenning van gemeenskappe tot op die subserievlak in sy hierargie moontlik maak. Die klassifikasie is teweeggebring deur gebruik te maak van die Braun–Blanquetmetode van tafel-sortering. Nege streeksgemeenskappe op verskeie hierargiese vlakke is geïdentifiseer en gekarteer. Nie-fynbos-gemeenskappe het die volgende ingesluit: Woud & Ruigte en Renosterstruikveld. Die grootste oppervlakte van die studiegebied was bedek met die volgende fynbos-gemeenskappe, Mesotrofiese Komposiet-Fynbos, Duinkomposiet-Fynbos, Droë Restioïde Fynbos, *Protea repens*-Proteoïde Fynbos, *Protea obtusifolia*–*Leucadendron meridianum*/P. *susannae*–*L. coniferum*-Proteoïde Fynbos, *L. platyspermum*–P. *compacta*–*L. xanthoconus*-Proteoïde Fynbos en Mesiese Ericoïde Fynbos. Dit was slegs moontlik om Woud & Ruigte-gemeenskappe te klassifiseer tot op die groepvlak. 'n Nuwe konsep Duinkomposiet-Fynbos op die subserie-vlak is geskep. Die meeste van die laagland-plantegroei van die Agulhasvlakte kan in alle ander opsigte geïntegreer word met Campbell se Fynbos-Bioom-plantegroei-konsepte. Die studie het dus enige regverdiging vir die behoud van 'n laagland-fynbosplantegroei-konsep omvergegooi. Aangesien ons die bekwaamhede van 'n aantal opgeleide plantkundiges gebruik het in die versameling van maklik-identifiseerbare strukturele en beperkte floristiese gegewens, was dit moontlik om die hele studie binne 18 maande te voltooi. Die gekarteerde gemeenskappe is voldoende vir die beplanning van bewaringsaksies en behels 'n essensiële beskrywende basis vir toekomstige studies oor die evolusie en handhawing van die spesies-verskeidenheid op die Agulhasvlakte. Die doeltreffendheid en effektiwiteit van ons benadering het dit moontlik gemaak om die studie te gebruik as 'n model vir vinnige plantegroei-klassifikasie van die veel-bedreigde plantegroei van die fynbos-bioom-laaglande.

**Keywords:** Classification, dominant taxa, fynbos, lowlands, structure

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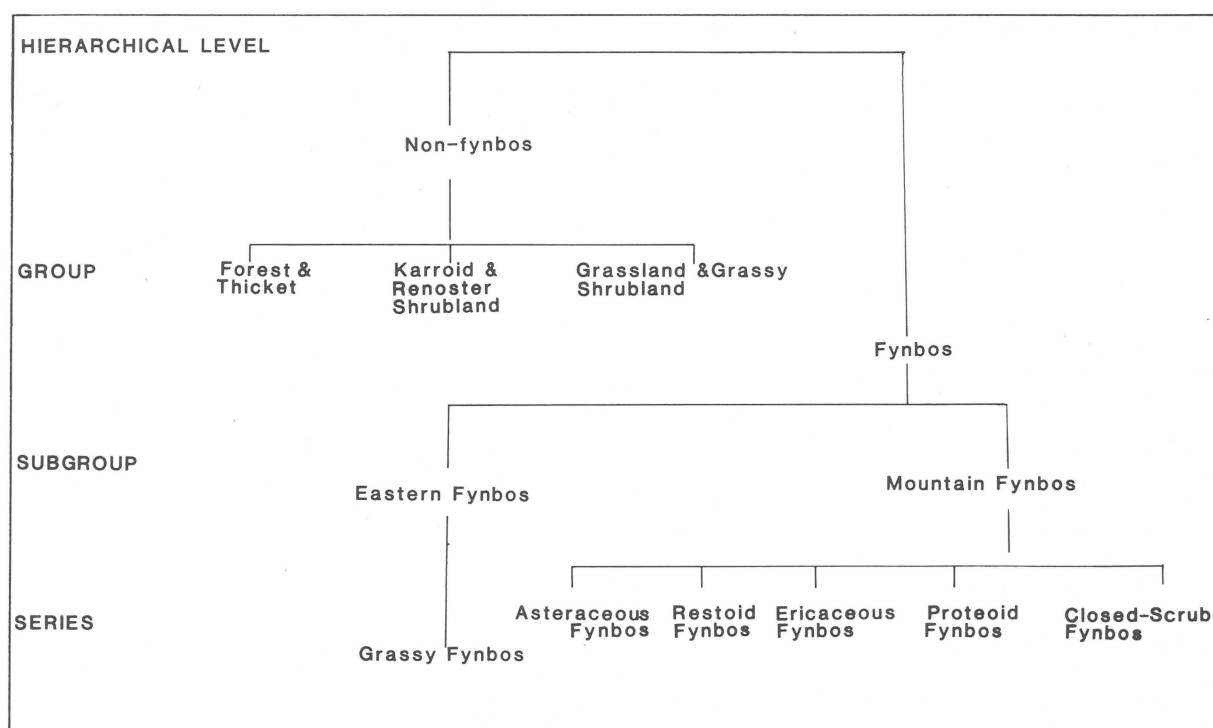
### Introduction

A detailed phytosociological analysis of the fynbos biome is practically and theoretically problematic (Campbell 1986a). Although many local and regional surveys (largely employing the Braun–Blanquet approach) have been published (e.g. see references in Scheepers 1983), the potential for geographical extrapolation is limited by high delta diversity (Kruger & Taylor 1979) of a flora in excess of 8 000 species (Bond & Goldblatt 1984). Even at a local scale, floristic characterization of communities is frustrated by a highly variable floristic structure which often reflects fire history more than underlying environmental gradients (Taylor 1985; Cowling 1987). To these problems must be added the poor taxonomic status of many fynbos genera resulting in a highly fluid nomenclature.

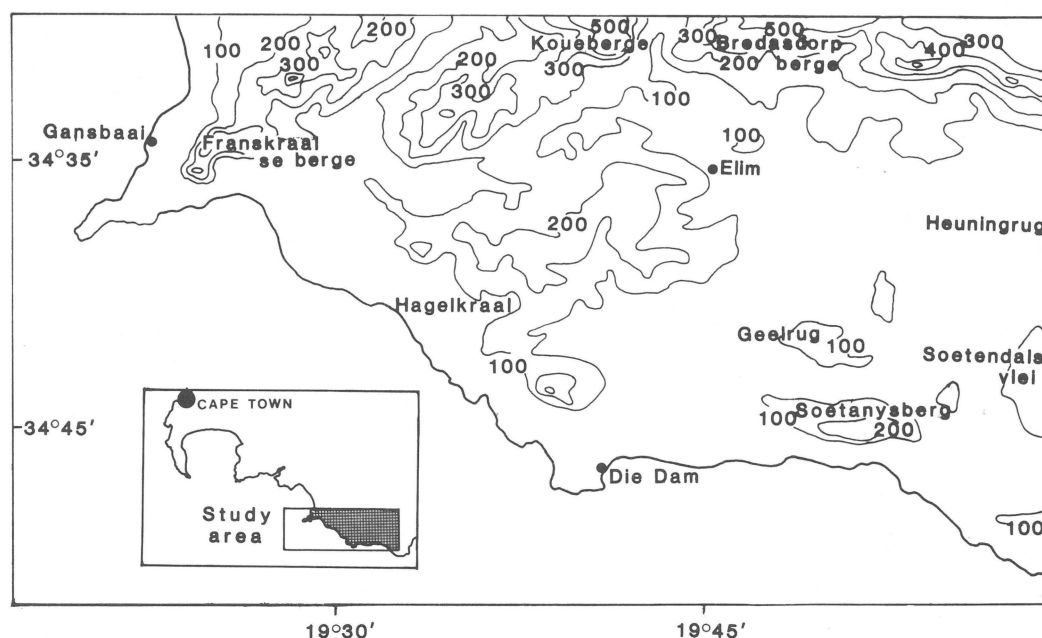
There is none the less an urgent need for a robust and meaningful classification of fynbos biome vegetation (Taylor 1978; Kruger 1979). Campbell (1985, 1986b)

addressed this problem creatively for mountain vegetation by developing a classification using structural characters, higher taxa and dominant species. His hierarchical classification is summarized in Figure 1. Although his vegetation concepts have been tested on a limited scale in the mountains (Campbell 1986b), no previous attempts have been made to extrapolate them to the lowlands of the biome.

In this study we applied Campbell's (1985) mountain vegetation concepts to the Agulhas Plain, a lowland region in the south-western corner of the fynbos biome (Figure 2). Most of the area's coastline comprises Milewski's (1979) Caledon Coast which has been studied in a programme to investigate biological convergence in mediterranean southern Africa and Australia (Milewski 1983; Milewski & Cowling 1985). We chose the Agulhas Plain for the following reasons. Firstly, the area includes a wide range of major fynbos biome vegetation groups making it ideal for applying and developing concepts. Acocks (1975) commented



**Figure 1** Campbell's (1985) hierarchical classification of mountain communities in the fynbos biome. Only the upper levels of the hierarchy are displayed.



**Figure 2** Topography and major localities in the Agulhas Plain. Contours are in meters.

on the vegetational complexity of the area when he stated: '... the fynbos of the limestone in the Bredasdorp division will have to be regarded as a distinct veld type, as will the dwarf fynbos of the Elim flats, when a detailed survey comes to be made'. Secondly, an inventory of vegetation resources is essential for conservation planning in the area. Like most of the lowlands of the fynbos biome (Taylor 1978; Boucher & Moll 1980) the conservation status of the Agulhas Plain is declining rapidly (Cowling, unpublished data). The map produced by Moll *et al.* (1984) is at a scale too small for regional planning. Finally, this exercise provides the descriptive basis for a research programme to study the impact of disturbance (fire, flower harvesting) on population structure of selected species and the evolution

and maintenance of plant species diversity of the Agulhas Plain flora.

### Study area

The study area, comprising the western part of the Agulhas Plain, includes about 1 500 km<sup>2</sup> of rolling landscape (Figure 2). Despite low topographical diversity when compared with the mountainous regions of the fynbos biome, the area has numerous widely contrasting soil types and land systems (Thwaites & Cowling 1988). These include the Bredasdorpberge land system (Table Mountain Group sandstone hills, up to 625 m elevation, and acid colluvial sands), Hagelkraal land system (Bredasdorp Formation limestone hills and neutral colluvial sands), Elim land

system (rolling shale lowlands with duplex soils and numerous remnant silcrete and ferricrete outcrops), Moddervlei land system (broad alluvial valleys and vleis with seasonally or permanently waterlogged duplex soils) and the Die Dam land system (Pleistocene to recent calcareous coastal dunes) (for details see Thwaites & Cowling 1988).

The climate of the area is relatively uniform. Along the coast mean annual rainfall ranges from 445 mm at Cape Agulhas to 454 mm at Gansbaai. Higher values would be recorded in the hills but data are lacking. Between 65 and 75% of annual precipitation occurs in the winter months between May and October. Average annual temperature ranges between 15 and 16°C. According to the UNESCO-FAO bioclimatic classification, the coastal part of the study area has an attenuated mesomediterranean climate and the inland part an accentuated mesomediterranean climate (Milewski 1979).

**Table 1** Physiognomic and floristically linked structural characters used in the survey of Agulhas Plain vegetation. Total cover, total woody, herbaceous and proteoid cover and the cover of non-sprouting proteoids, non-proteoid leptophylls (excluding ericoids and Ericaceae), non-proteoid nanophylls-mesophylls, ericoids, Ericaceae and restioids were estimated in five height classes (0–0.25 m, 0.25–1 m, 1–2 m, 2–5 m, 5–10 m). See Campbell (1985) for details

Leaf size (leptophyll, nanophyll, microphyll, mesophyll)
Leaf texture (sclerophyll, orthophyll, fleshy, succulent)
Leaf form arrangement (ericoid <sup>1</sup> , elytropappoid)
Proteoid leaves (isobilateral leaves of the Proteaceae; sprouters and non-sprouters were distinguished)
Deciduousness
Climbers
Rosulate succulents (e.g. <i>Aloe</i> spp.)
Spinescence (leaf and stem)
Penaeaceae
Bruniaceae
Ericaceae
Sedges (aphyllous, narrow-leaf, broad-leaf)
Grasses (aphyllous, other)
Restioids (Restionaceae)

<sup>1</sup>Non-ericaceous

Acocks (1953) mapped the entire area as coastal fynbos (veld type no. 47). Moll *et al.* (1984) recognized four vegetation types in the region: Strandveld, Limestone Fynbos, Elim Fynbos, and Mesic Mountain Fynbos.

## Methods

### Approach

The study area is species-rich, including more than 1 700 species (Cowling, unpublished data). Since our aim was to produce, in a relatively short time, an ecologically meaningful classification generating units which could be recognized by managers and non-botanists, it seemed obvious to use Campbell's (1986a) structural approach. This would also allow us to test the applicability of his system to lowland vegetation. Although the approach is essentially structural, it does incorporate floristic data in the form of dominant taxa and floristically linked structural characters. The epistemological basis of the approach is described in Campbell (1986a).

### Data collection

Data were collected over 5 days in April 1986 by 16 fynbos botanists working in groups of four and under the overall leadership of R.M.C. and B.M.C. Each group was instructed to sample the full range of mature vegetation (more than 10 years since the last burn) encountered each day in the area allocated to them for field work. A total of 97 plots of 10 × 10 m were sampled throughout the study area. In each plot, environmental (soils, rock cover, topography, slope and aspect), floristic (dominant taxa: > 10% cover) and structural data (Table 1) were collected. These structural characters were a subset of those used by Campbell (1985) and were chosen to differentiate communities at or above the sub-series level. Nomenclature is according to Bond & Goldblatt (1984).

### Data analysis

Preliminary sorting of plots into vegetation categories was done using Campbell's (1985) keys. Eleven fynbos plots would not key out at the series level and were excluded from the analysis. The final classification was produced by sorting the plot by structural character/dominant species table according to the Braun-Blanquet approach (Campbell 1986a). Only the structural characters with strong

**Table 2** Plant communities of the Agulhas Plain

Community	Hierarchical level (Campbell 1985)	Synonymy (Moll <i>et al.</i> 1984)	Land Systems (Thwaites & Cowling 1988)
Forest & Thicket	Group	South Coast Strandveld (in part)	Die Dam, Hagelkraal
Karroid & Renoster Shrubland	Group	South Coast Renosterveld	Elim, Moddervlei
Renoster Shrubland	Series	(not mapped in study area)	
Fynbos	Group		
Asteraceous Fynbos	Series		
Mesotrophic A.F.	Sub-series	Elim Fynbos	Elim
Dune A.F. <sup>1</sup>	Sub-series	Dune Fynbos	Die Dam
Restioid Fynbos	Series	Sand Plain Fynbos	
Dry R.F.	Sub-series		Moddervlei
Proteoid Fynbos	Series		
<i>Protea repens</i>	? Type	Mesic Mountain Fynbos	Elim (silcrete and ferricrete)
<i>P. compacta</i> , <i>Leucadendron xanthoconus</i> , <i>L. platyspermum</i>	? Type	Mesic Mountain Fynbos	Bredasdorpberge
<i>P. susannae</i> , <i>L. coniferum</i> , <i>P. obtusifolia</i> , <i>L. meridianum</i>	? Type	Limestone Fynbos	Hagelkraal
Ericaceous Fynbos	Series		
Mesic E.F.	Sub-series	Mesic Mountain Fynbos	Bredasdorpberge

<sup>1</sup>New sub-series in Campbell's (1985) scheme

differential properties were included in the final table. Since Campbell's (1986a) attempts in using numerical classification techniques were unsuccessful, we avoided these.

### The plant communities

According to Campbell's (1985) scheme, there are three major vegetation groups on the Agulhas Plain: two non-fynbos groups (Forest & Thicket, Renoster Shrubland) and fynbos (Tables 2 & 3). Four fynbos series (Asteraceous, Restioid, Proteoid, Ericaceous), each with at least one sub-series, were recognized. For practical reasons it was not possible to map units at the same hierarchical level: groups are mapped with sub-series and even lower level communities (Figure 3, Table 2).

#### Forest & Thicket

##### Differential features

This group lacked typical fynbos differential features such as restioids, Ericaceae, proteoids and sedges (Campbell 1986b). It was differentiated from other groups by its height and the high cover of trees and shrubs with large (> leptophyll) non-proteoid leaves (Table 3). Climbers, stem spines, succulents and deciduous shrubs and trees were also common.

Three structural types occurred on the Agulhas Plain although it was not possible to place them in any of Campbell's (1985) series. The tallest type (canopy 5–10 m) was structurally similar to Campbell's (1985) Afromontane Forest but differed floristically. The lower forest (canopy 2–5 m) included some plots with a well-developed herbaceous ground layer, linking them to Campbell's (1985) Eastern Forest & Thicket. The thicket (canopy 1–2 m) did not have any of the differential features of Campbell's (1985) thicket types.

##### Floristics

The forests of the Agulhas Plain differed from other forests in the south-western Cape in having a composition not typically afromontane (cf. Campbell & Moll 1977; McKenzie 1978). Dominant canopy trees (Table 3) included *Sideroxylon inerme*, *Celtis africana*, *Olinia ventosa* and *Apodytes dimidiata* linking these forests to the dune forests of the Tongaland-Pondoland region (Moll & White 1978). The thicket types, dominated by the large-leaved *Euclea racemosa*, *Sideroxylon inerme*, *Olea exasperata* and *Rhus* spp. were typical of lowland, largely dune, thickets in the south-western Cape.

##### Environment

Forest and thicket was most common on deep colluvial sands derived from Bredasdorp Formation limestone and on calcareous coastal dunes. Isolated thicket clumps were found on 'heuweltjies' (Boucher & Moll 1980) in the south east of the study area. With the prolonged absence of fire, thicket initials will establish on these sites and develop into a thicket or forest which is not generally fire-prone (Taylor 1961; Tinley 1985; Cowling & Pierce 1988). Forest & Thicket soils were the most fertile on the Agulhas Plain (Thwaites & Cowling 1988), due in part to plant-induced organic enrichment.

##### Distribution

Within the study area, the only mappable Forest & Thicket patches were those studied by Taylor (1961) (Figure 3). The taller *Sideroxylon-Celtis* forest is unique to the Agulhas Plain. Vegetation similar to the thicket types, and mapped largely as Strandveld by Moll *et al.* (1984), has been recorded in similar habitats (mainly quaternary alkaline sands) in the Riversdale district (Muir 1929), De Hoop

Nature Reserve (van der Merwe 1977), Cape Hangklip (Boucher 1978), Cape Flats (Taylor 1972) and Cape of Good Hope Nature Reserve (Taylor 1985). Indeed, dune thickets throughout the southern and south-western Cape coastal region show strong structural and floristic similarity (Cowling 1984) and should be recognized as a distinct series within the Forest & Thicket group.

#### Renoster shrubland

##### Differential features

In Campbell's (1985) scheme, Renoster Shrubland is a series within the non-fynbos Karroid & Renoster Shrubland group. The chief differential characters of this group are low total cover, high succulent and elytopappoid cover, and the presence of annuals, rosulate succulents and stem succulents (Campbell 1986b) (cf. Table 3). Renoster Shrubland was distinguished from other communities on the Agulhas Plain by having a low overall cover, high cover of grasses and the highest cover and constancy of elytopappoids and leaf spines (cf. Campbell 1985). Campbell (1985) acknowledged that his Renoster Shrubland concept needed subdivision and tentatively suggested that one subset be a grassy type having a high (> 30%) cover of perennial grasses.

##### Floristics

Differential dominant species were the graminoids *Themeda triandra*, *Ficinia tristachya*, *Pentaschistis colorata*, and *Cynodon dactylon* (Table 3). Although it was also a fairly frequent dominant in Mesotrophic Asteraceous Fynbos, (see below), *Elytropappus rhinocerotis* was recorded as a dominant in all Renoster Shrubland plots (Table 3). Other dominant shrubs included *Metalasia muricata*, *Helichrysum patulum*, and *Stoebe capitata*.

##### Environment

On the Agulhas Plain, Renoster Shrubland was confined largely to the moderately fertile duplex soils derived from Bokkeveld Group shale (Elim land system) (Thwaites & Cowling 1988). It also occurred in the broad, level valleys of the Moddervlei land system, where acid infertile sands overlies saline clay. Mesotrophic Asteraceous Fynbos (see below) replaces Renoster Shrubland where reworked ferricrete occurs as a substantial stoneline in the loamy A horizon of the duplex soils. It was not possible to map these two communities separately (Figure 3).

##### Distribution

In broad definition, Renoster Shrubland on the Agulhas Plain is similar to the grassy communities of the southern and south-eastern Cape coastal forelands (Boucher & Moll 1980; Cowling 1984; Cowling & Pierce 1986).

#### Mesotrophic Asteraceous Fynbos

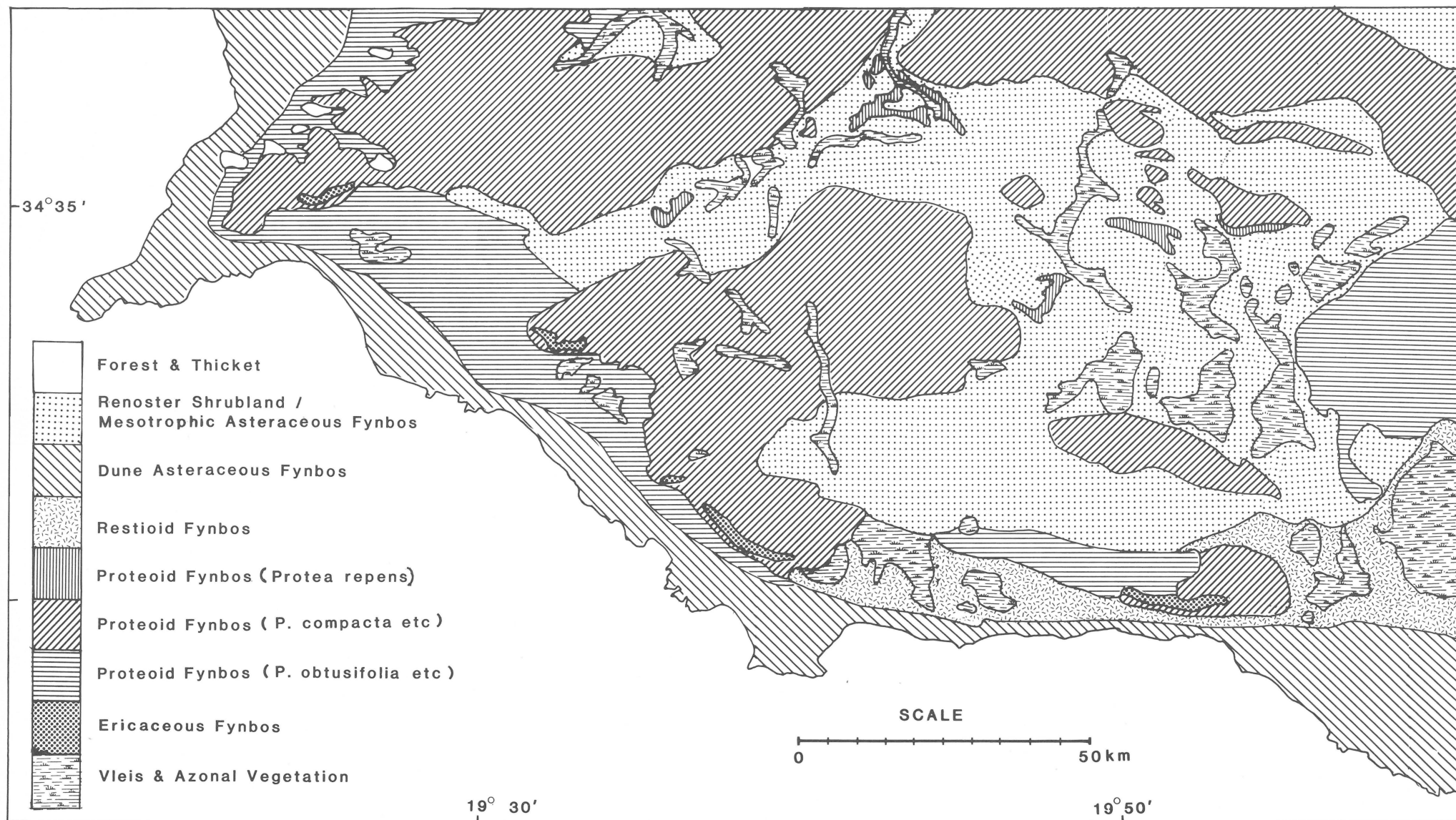
##### Differential features

The remaining communities all qualify as fynbos according to Campbell's (1985) definitions. Relative to other fynbos series, Asteraceous Fynbos generally has a lower total cover (30–70%), a high cover of non-ericaceous ericoids (Asteraceae, Rhamnaceae, Thymelaeaceae) relative to restioids and sedges, and the occasionally high cover of elytopappoids, grasses, succulents and fleshy-leaved shrubs (Campbell 1986b). Many of these characters link Asteraceous Fynbos to non-fynbos groups, particularly Karroid & Renoster Shrubland (e.g. Renoster Shrubland). Asteraceous Fynbos occupies the driest sites in the mountains of the fynbos biome.

The Asteraceous Fynbos on the Agulhas Plain, previously described as Elim Fynbos (Acocks 1953; Moll *et al.* 1984), included a complex array of structural types ranging from







**Figure 3** Vegetation map of the Agulhas Plain. Numerous smaller pockets of Forest & Thicket occur within Dune Asteraceous Fynbos and Proteoid Fynbos (*P. obtusifolia* etc). Many unmappable patches of Proteoid Fynbos (*P. repens*) occur on isolated silcrete and ferricrete remnants within the Renoster Shrubland/Mesotrophic Asteraceous Fynbos mosaic. See Table 2 for the hierarchical level of mapped units.

There is nothing unique to this community in terms of structure and plots could easily be accommodated in Campbell's (1985) structural scheme. The dwarf nature of the communities (Acocks 1953) is not diagnostic as many similar communities, often with low proteoids (*Leucadendron* spp.), e.g. Katbakkies Dry Asteraceous Fynbos, can be found in dry inland mountains. Seven of the 12 plots are grouped into the Witteberg type, which is mostly characterized by high elytopappoid cover, whereas four plots fall into the Bantamskop type which has a high cover of Ericaceae and usually a high grass cover. One plot was classified into the Restioid Fynbos series.

#### Floristics

Floristically, the community was highly variable. Common dominant proteoids included the endemics, *Leucadendron elimense*, *L. modestum* and *L. laxum* (Table 3). The last two mentioned species are apparently resilient to frequent burning and heavy grazing. Among the non-ericaceous ericoid component, *Metalasia muricata*, *Phylica ericoides*, *Passerina galpinii* and *Disparago anomala* were dominant in some plots. Ericaceous shrubs were represented by many species including an unidentified species of a minor genus of the Ericaceae, *Erica lasciva*, *E. brunifolia* and *E. nudifolia*. The only dominant grass was *Pentaschistis colorata*. *Elytropappus rhinocerotis* occurred in all plots and was dominant in many, linking this type to Renoster Shrubland (Table 3).

#### Environment

Like Renoster Shrubland, Mesotrophic Asteraceous Fynbos occurs on the fine-grained soils of the Elim land system. However, soils always have substantial reworked ferricrete in the A horizon. This community often occurs as a broad belt between Proteoid Fynbos (*Protea repens*) and Renoster Shrubland on a catenal sequence from ferricrete (top-slope) to alluvial bottomland (Thwaites & Cowling 1988).

#### Distribution

This community is apparently confined to the Agulhas Plain. Structurally but not floristically similar vegetation may well occur in other lowland regions of the southern and south-western Cape.

#### Dune Asteraceous Fynbos

##### Differential features

Dune Asteraceous Fynbos forms a new sub-series within Campbell's (1985) scheme. Cowling (1984) also recognized dune fynbos as a floristically distinct fynbos biome community. It differs from Mesotrophic Asteraceous Fynbos by having a consistently high cover of non-ericaceous ericoids and from all other sub-series in lacking proteoids and having a high constancy of nano- to mesophyllous non-proteoid shrubs (Table 3). The cover of Rutaceae (especially *Agathosma* spp.), which we did not record in this study, would also be a differential feature of Dune Asteraceous Fynbos (see Muir 1929).

##### Floristics

Dominant ericoid shrubs were *Passerina paleacea*, *Agathosma collina*, *Metalasia muricata* and *Phylica ericoides* (Table 3). Dominant graminoids included *Ischyrolepis eleocharis*, *Calopsis fruticosus* and *Ficinia lateralis*: the first mentioned species being characteristic of dune fynbos throughout the biome (Cowling 1984). *Euclea racemosa*, *Myrica quercifolia*, *Pterocelastrus tricuspidatus* and *Rhus* spp. were the common and dominant large-leaved, non-proteoid shrubs.

#### Environment

Dune Asteraceous Fynbos was confined to deep, well-drained, calcareous sands (Fernwood form) of the recent coastal dunes (Die Dam land system) (Thwaites & Cowling 1988). These wind-blasted areas are some of the driest on the Agulhas Plain. With the prolonged absence of fire, this community is replaced by thicket, especially in mesic sites.

#### Distribution

Dune Asteraceous Fynbos occurs on coastal dunes throughout the fynbos biome from Port Elizabeth to Langebaan (Cowling 1984). In the study area, this type was mapped erroneously as South Coast Strandveld by Moll *et al.* (1984). Floristically and structurally similar communities have been described from the Riversdale district (Muir 1929), De Hoop Nature Reserve (van der Merwe 1977), Cape Hangklip (Boucher 1978), Cape Flats (Taylor 1972) and Cape of Good Hope Nature Reserve (Taylor 1985).

#### Dry Restioid Fynbos

##### Differential features

Restioid Fynbos is differentiated from other fynbos series by having a high graminoid cover (> 60%) of restioids, and less usually sedges, and a low cover of shrubs (mostly < 30%) particularly those > 1,5 m (Campbell 1986b). Restioid Fynbos, for the most part being a dry fynbos series, shares a number of features with Asteraceous Fynbos. It occurs on sites more mesic than the latter series and is typical of conditions which are limiting for shrub growth [seasonally waterlogged sites and shallow soils on north aspects of mountains (Campbell 1985)].

There is no key to the three sub-series of Restioid Fynbos described by Campbell (1985). However, in this study, most plots had features consistent with Dry Restioid Fynbos, such as low cover and the occasional presence of elytopappoids (Table 3). A distinctive feature of this community on the Agulhas Plain was the high cover of low (< 1,0 m) leptophyllous proteoids (Table 3).

##### Floristics

The community was dominated by a restioid (*Chondropetalum tectorum*) and a non-sprouting proteoid (*Leucadendron linifolium*) (Table 3). Other dominants included the restioids *Chondropetalum rectum* and *Thamnochortus erectus* and leptophyllous shrubs, *Cliffortia ferruginea* and *Elytropappus rhinocerotis*.

#### Environment

On the Agulhas Plain, Dry Restioid Fynbos was confined to the low-lying country of the Moddervlei land system adjacent to the Soetanyssberg and Soetendalsvlei (Figure 3). Soils (usually < 1 m) were colluvial sands of mixed origin (calcareous sands or T.M.G. sandstone) but were always seasonally waterlogged and usually neutral to alkaline (Thwaites & Cowling 1988). The underlying bedrock was either T.M.G. sandstone or Bredasdorp Formation limestone.

#### Distribution

Lowland communities which are probably Dry Restioid Fynbos types occur extensively on the south-western coastal lowlands between Riversdale and the Cape Peninsula (Muir 1929; Taylor 1972; Milewski 1977; van der Merwe 1977; Boucher 1978; Taylor 1985) as well as the western lowlands (Boucher & Jarman 1977; Milewski & Esterhuysen 1977). However, none of these correspond floristically to the Agulhas Plain community.



## Proteoid Fynbos

### Differential features

Proteoid Fynbos is unusual in Campbell's (1985) scheme in that the series is differentiated largely on the basis of a single structural character ( $> 10\%$  cover of  $> 1.0$ -m tall seed-regenerating proteoids) and, with the exception of Mesotrophic Proteoid Fynbos (with a grassy understorey), the sub-series is differentiated by dominant proteoid overstorey species. An obvious problem with this concept of Proteoid Fynbos is the vulnerability of the proteoid overstorey to a reduction in cover or local extinction as a result of fire regime (Bond *et al.* 1984; van Wilgen & Viviers 1985) [see Campbell (1985) for an extended discussion].

Proteoid Fynbos is the most widespread community on the Agulhas Plain (Figure 3). With the exception of *Protea repens*, none of the proteoid dominants in the study area were recorded in the mountains studied by Campbell (1985) so it was not possible to use these as differential characters in his classification. However, on the basis of understorey characteristics [e.g. features shared with Asteraceous Fynbos, presence of large-leaved non-proteoid shrubs, lower overall stature, lack of grasses (Table 3)], the plots would probably classify as Dry Proteoid Fynbos. A further problem with Campbell's (1985) concept in the study area was that in five of the 38 plots in this community, the dominant proteoids were  $< 1.0$  m high. This included species such as *Leucadendron meridianum*, *L. platyspermum*, *L. xanthoconus*, *Protea obtusifolia* and *P. repens*. It may be that this height class is too stringent for characterizing proteoid fynbos on the dry, windy lowlands. However, relaxing this requirement would mean including Mesotrophic Asteraceous Fynbos dominated by low seed-regenerating *Leucadendron* spp. and *L. linifolium*-dominated Restioid Fynbos in the Proteoid Fynbos concept (Table 3). This problem could be solved by excluding leptophyllous seed-regenerating proteoids (e.g. *L. linifolium*) from the concept; by a fuller structural characterization of the understorey; or by defining characteristic proteoids for the lowlands as Campbell (1985) has done for the mountains.

On the basis of dominant proteoids it was possible to recognize three major communities of Proteoid Fynbos on the Agulhas Plain (Tables 2 & 3). These would probably qualify as types in Campbell's (1985) scheme but no attempt was made to formalize nomenclature. The type dominated by *Protea repens* was characterized by the low but frequent cover of elytopappoids, low restioid cover and the occasional presence of other characters (e.g. succulents, grasses) linking it to Mesotrophic Asteraceous Fynbos. The second type comprised two floristically distinct but structurally related communities, characterized by the species pairs *P. susannae*–*Leucadendron coniferum* and *P. obtusifolia*–*L. meridianum*. Structurally, the former is distinguished from the latter by having a high cover of restioids and ericaceous shrubs. Features which these communities share include the occasionally high cover of ericoids and the common occurrence but moderately low cover ( $> 20\%$ ) of nano-mesophyllous, non-proteoids. Both these features link this type to Dune Asteraceous Fynbos. Furthermore, as with the latter community, a high constancy and cover of Rutaceae (*Acmadenia*, *Adendandra*, *Euchaetes*) would be a good differential feature. The final Proteoid Fynbos type was dominated by *Leucadendron platyspermum*, *L. xanthoconus* and *P. compacta*, although all three species never co-occurred in a single plot. The understorey was largely restioid but a relatively high cover of ericaceous shrubs and the common occurrence of broad-leaved sedges, *Penaeaceae* and *Bruniaceae* linked some plots in this type to Ericaceous Fynbos (see below).

### Floristics

The three types would probably include a great number of formally characterized floristic communities (Table 3). Co-dominants in the *Protea repens* type included the proteoids: *Leucadendron stelligerum*, *L. modestum*, *L. xanthoconus*, *Leucospermum pedunculatum* and *Protea longifolia*; asteraceous shrubs: *Metalasia muricata*, *Stoebe capitata* and *Elytropappus rhinocerotis*; ericaceous shrubs: *Nagellocarpus serratus* and *Thoracosperma puberulum*; graminoids *Ficinia tristachya*, *Ischyrolepis capensis* and *Rhodocoma fruticosa*.

The only common dominant shared between the *Protea susannae* and *P. obtusifolia* communities was *Thamnochortus guthrieae* (Table 3). Other co-dominants in the former community included ericoids: *Passerina vulgaris*, *Metalasia muricata* and *Euchaetes burchellii*; large-leaved non-proteoids: *Myrica quercifolia* and *Rhus laevigata*; restioids: *Hypodiscus albo-aristatus* and *Restio triticeus*. Co-dominants in the *P. obtusifolia* community included ericoids: *Adenandra obtusata* and *Stilbe ericoides*; limestone endemic proteoids: *Leucadendron muirii*, *Leucospermum truncatum*, *L. patersonii* and *Mimetes saxatilis*; ericaceous shrubs: *Erica propinqua*; large-leaved non-proteoids: *Chrysanthemoides monilifera*; restioids: *Thamnochortus paniculatus* and *Ischyrolepis leptoclados*.

Co-dominants in the floristically variable *Leucadendron platyspermum*–*Protea compacta*–*L. xanthoconus* type (Table 3) included occasional proteoids: *Aulax umbellata*, *Leucadendron gandogerii*, *L. salignum* and *Protea longifolia*; numerous ericaceous shrubs: *Erica filipendula*, *E. longiaristata*, *E. longifolia*, *E. melanacme*, *E. plukenetii*, *Blaeria klotzschii*, *Syndesmanthus gracilis* and *S. sympiezoides*; brunioids, *Staavia radiata* and *Brunia laevis*; restioids: *Restio similis*, *Calopsis membranacea*, *Elegia filacea*, *Staberoha* spp. and *Thamnochortus erectus*; cyperoids: *Tetraria bromiodes*, *T. cuspidata* and *T. fasciata*.

### Environment

The *Protea repens* type was confined to the ferricrete and silcrete remnants of the Elim land system (Thwaites & Cowling 1988). The shallow sandy soils overlying these outcrops are nutritionally similar to those derived from T.M.G. sandstones. The shallow calcareous sands of the Bredasdorp Formation (Hagelkraal land system) supported the *P. obtusifolia*–*Leucadendron meridianum* community while the *P. susannae*–*L. coniferum* community was confined to deep colluvial neutral sands derived from the same formation. The boundary between these floristically distinct communities is extremely abrupt and coincides with the occurrence of limestone outcrops. The remaining Proteoid Fynbos type was restricted to acid infertile sands derived from T.M.G. sandstones (Bredasdorpberge land system). Plots dominated by *L. platyspermum* were confined to shallow, gravelly soils on drier sites (e.g. Geelrug; Figure 2) whereas dense stands of *P. compacta* occurred on deep colluvial sands especially at the base of the Soetansberg and on the quartzitic uplands north of Hagelkraal. *L. xanthoconus* was common on both shallow rocky soils and deep sands and in many plots was the only dominant proteoid. It is possible that this species is more resilient to variations in fire regime (Le Maitre 1987) than the weakly serotinous *P. compacta* which has been eliminated over much of its potential range on deep colluvial sands.

### Distribution

With the possible exception of the *Protea repens* type, none of the Proteoid Fynbos communities of the Agulhas Plain are found in the mountains of the fynbos biome. Although vegetation dominated by *Leucadendron xanthoconus* is



found extensively in the mountains of the south-western Cape (Kruger 1974; Boucher 1978; Taylor 1985), both *L. platyspermum* (Williams 1972) and *P. compacta* (Rourke 1980) are virtually confined to the study area. Boucher & Shepherd (1988) have described Proteoid Fynbos, dominated by *P. burchellii* and *P. repens*, on acid colluvial sands of the west coastal lowlands. Muir (1929) describes a community dominated by *P. lanceolata* and *P. repens* on deep sands near Albertinia on the south coastal forelands which is probably a form of Dry Proteoid Fynbos. Moll *et al.* (1984) would include all the above communities in their sand plain lowland fynbos concept.

Proteoid Fynbos on soils derived from the Bredasdorp Formation limestones are widespread in the southern coastal forelands between the study area and the Gouritz River. Communities dominated by *Protea obtusifolia* and *Leucadendron meridianum* have been described by van der Merwe (1977) at De Hoop Nature Reserve and by Muir (1929) in the Riversdale district. The flora is rich in local and regional endemics (Taylor 1978; Cowling, unpublished data). Communities with *P. susannae* and *L. coniferum* as co-dominants are apparently confined to the study area. *L. coniferum*-dominated vegetation on deep alkaline sands has been described at Cape Hangklip by Boucher (1978) and in the Cape of Good Hope Nature Reserve by Taylor (1985). *L. coniferum* is replaced by *Leucospermum praecox* as a co-dominant with *P. susannae* on colluvial Bredasdorp Formation sands in the Riversdale district (Muir 1929).

### Mesic Ericaceous Fynbos

#### Differential features

Both Ericaceous Fynbos and Asteraceous Fynbos are leptophyllous shrublands but the former is distinguished by a high cover of restioids and ericaceous shrubs (Campbell 1985). Other characteristic features are the high constancy of Penaeaceae and Bruniaceae and the high cover of sedges (Table 3). The plots in the study area were classified as Mesic Ericaceous Fynbos on the basis of high (> 30%) cover of ericaceous shrubs and of the Nuweberg type because of the presence of broad-leaved sedges (*Tetraria thermalis*) (Campbell 1985). High ericaceous cover was also recorded in Mesotrophic Asteraceous Fynbos in the study area (Table 3), thus creating problems in using Campbell's (1985) key which emphasizes this character in defining Ericaceous Fynbos. This problem can be circumvented by incorporating the high cover of restioids as a key feature for Ericaceous Fynbos.

#### Floristics

Mesic Ericaceous Fynbos in the study area had a distinctive flora dominated by ericaceous shrubs including *Erica coccinea* and *Nagellocarpus serratus* (Table 3). *Leucospermum cordifolium* was occasionally dominant while dominant restioids included *Elegia* cf. *persistens* and *Chondropetalum deustum*. The sedge *Tetraria thermalis* was consistently dominant while *Nebelia paleacea* (Bruniaceae) was often present but rarely dominant.

#### Environment

This community was rare in the study area, where it was confined to steep south-facing slopes of the coastal T.M.G. sandstone hills between Soetanysberg and Gansbaai (Figure 3). Soils were shallow, rocky and infertile with relatively high levels of organic carbon and unusually high levels of sodium, probably resulting from exposure to persistent salt-laden onshore winds (Thwaites & Cowling 1988).

### Distribution

Ericaceous Fynbos is more a feature of wet south-facing slopes of the coastal mountains than the low hills and sand plains of the lowlands (Campbell 1985). Its occurrence in the study area is a result of suitable microclimatic conditions afforded by steep seaward-facing slopes which are much wetter than adjacent areas, due to orographically increased rainfall, maximum exposure to fog and reduced evapotranspirational demands. It is possible that these communities may occur on similar sites on Potberg, to the east of the study area. No Ericaceous Fynbos was observed on the Bredasdorpberge.

### Azonal and vlei vegetation

Azonal and vlei vegetation was not studied in this survey although it covers a large part of the study area (Figure 3). Much of the azonal vegetation would be classified as Campbell's (1985) Azonal Restioid Fynbos. There were also extensive halophytic communities dominated by *Salicornia* spp., vlei-fringing reeds (*Phragmites* spp.) and other fresh water macrophytic communities not covered in Campbell's (1985) scheme.

### Discussion

#### Congruence with Campbell's (1985) scheme

Campbell's (1985) scheme was developed for mature vegetation of the fynbos biome mountains. The present study area included mostly lowland communities although there were substantial areas of hills and low mountains (Figure 2). Generally, the vegetation of the Agulhas Plain could be incorporated into Campbell's (1985) scheme to the series level for all groups, except Forest & Thicket. This is because Campbell (1985) never sampled dune thickets and the fact that the Agulhas Plain forests are unique (Taylor 1961). At the sub-series level, it was necessary to develop a new concept within Asteraceous Fynbos, namely Dune Asteraceous Fynbos. We made little attempt to evaluate concepts below the sub-series level and indications are that this could be problematic. However, in all other respects, this application of Campbell's (1985) concepts proved their robustness and general applicability.

This study also heralds the demise of the lowland fynbos concept. This concept can be traced to Acocks (1953) who first distinguished coastal and mountain forms of fynbos. This distinction has been upheld by Taylor (1978), Kruger (1979) and most recently, Moll *et al.* (1984). It is clear that with the exception of Dune Asteraceous Fynbos, there are no structurally defined fynbos communities confined to the coastal lowlands. The argument that the lowland fynbos concept is valid on a floristic basis is also easily rejected, since many types of mountain fynbos are as floristically unrelated to each other as they are to lowland fynbos (cf. Kruger & Taylor 1979). We recommend the rejection of both the lowland and mountain fynbos concepts and their replacement by an all-encompassing fynbos concept at the group level as defined structurally by Campbell (1985). This would imply the elimination of the sub-group level in Campbell's (1985) hierarchy (Figure 1). We do not accept that a single character, grassiness justifies the erection of a distinct sub-group (i.e. eastern fynbos) within Campbell's (1985) scheme.

#### Effectiveness of the approach

Our approach in classifying the vegetation of the Agulhas Plain was to use a team of trained botanists to collect limited but diagnostically important structural and floristic data. The bulk of the fieldwork was completed in under 5 days and data were analysed in sporadic bursts, largely by

one of us (R.M.C.) over the following year. The entire task was completed in under 18 months. By even the most optimistic standards, a thorough phytosociological survey of the study area would have taken a full-time botanist at least 3 years, probably more.

An obvious question is whether the ultimate communities (mappable units) described in this study are adequate for conservation planning. We believe they are. Lower level communities would not be mappable, making it difficult to assess their gross conservation status (i.e. remaining natural or semi-natural vegetation). Limited floristic sampling could be done to ascertain the degree of floristic variation within and between communities and to quantify patterns of local and regional endemism. The study provided an adequate descriptive basis for future research on the evolution and maintenance of species diversity on the Agulhas Plain.

There are, however, distinct disadvantages to co-operative data collection involving a large team of researchers. Certain biases in our data were evident (Campbell, unpublished data) and a number of plots had to be rejected, both because data were collected incorrectly and also resulting from the location of plots in immature or transitional sites. These biases could have been overcome by a more thorough briefing prior to data collection. We believe that in using our approach, data could be collected effectively and efficiently by non-botanists. More generally, this approach could be used as a model for rapid vegetation classification in the critically threatened lowlands of the fynbos biome.

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